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Depressed democracy, environmental injustice: Exploring the negative mental health implications of unconventional oil and gas production in the United States

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ABSTRACT

Unconventional oil and gas (UOG) production has rapidly expanded, making the U.S. the top producer of hydrocarbons. The industrial process now pushes against neighborhoods, schools, and people's daily lives. I analyze extensive mixed methods data collected over three years in Colorado – including 75 in-depth interviews and additional participant observation – to show how living amid industrial UOG production generates chronic stress and negative mental health outcomes, such as self-reported depression. I show how UOG production has become a neighborhood industrial activity that, in turn, acts as a chronic environmental stressor. I examine two key drivers of chronic stress – uncertainty and powerlessness – and show how these mechanisms relate to state-level institutional processes that generate patterned procedural inequities. This includes inadequate access to transparent environmental and public health information about UOG production's potential risks and limited public participation in decisions about production, with negative implications for mental health.

1. Introduction

American unconventional oil and gas production has rapidly expanded over the last decade, with the U.S. now the top global producer of hydrocarbons [1]. As unconventional oil and gas production (hereafter UOG production) spreads, it pushes against neighborhoods, schools, and people's daily lives. The drilling and hydraulic fracturing phases of UOG production involve noisy, odorous, disruptive, and unhealthy processes [2], as operators drill vertically to first reach the shale layer and then horizontally for up to four miles, setting off multiple explosions along the directional pipe, and then pumping millions of gallons of water, sand/ceramic, and chemicals into the wellbore to extract oil and/or gas from the shale layer. Extensive infrastructure like compressor stations and pipelines carry out other phases of production [3]. Yet, we still know relatively little about how UOG production's encroachment into communities affects people's stress experiences and their mental health. Below, I provide robust evidence that chronic environmental stress from living near industrial UOG production can cause negative mental health outcomes for members of the public – with people's stress made chronic by institutionalized procedural inequities.

Because UOG production is an industrial set of processes, there have been strong public responses to allowing the activity where people live, work, and play [4]. Heavily drilled places like Colorado – where I conducted this multi-year, multi-sited study – have histories of oil and gas production, but the pace and scale are different now and can occur alongside population booms. In the U.S., lack of federal regulation since the 2005 Energy Policy Act facilitated UOG operators' rapid spread into residential areas and other high-occupancy community spaces, like schools, zoned for other purposes [5–7]. Production has boomed as a result. For instance, in Colorado, since 2010, natural gas extraction has increased by about 51% and crude oil production has quadrupled [1]; over 378,000 Coloradans are estimated to live within 1.6 km of oil and/or gas wells [8]. Despite over 55,000 wells operating across Colorado, only five field managers and eighteen field officers enforce regulations via state agencies like the Colorado Oil and Gas Conservation Commission – which has not yet denied a drilling permit [9]. As such, UOG production's pace and scale create more opportunities for environmental public health effects and chronic environmental stressors to emerge, as industrial processes mix with public, residential, commercial, and agricultural spaces [10].

While social scientists know that industrial activities can cause chronic or increased stress and negatively impact mental health [10,11], UOG production's creation of stress and its consequent impacts to mental health and quality of life deserve more attention as the practice proliferates [12]. Only a handful of studies examine stressors

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and mental health in this context; even fewer examine institutional mechanisms related to information access and public participation. None, to my knowledge, examine the two together. *Here, I begin to draw these important links between chronic environmental stress created by UOG production, the institutional contexts that exacerbate this stress, and their negative outcomes for mental health.*

Using rich ethnographic data collected in multiple communities across northern Colorado, I show how UOG production near people's homes drives stress experiences that go beyond the mere presence of industrial land uses in neighborhoods. Procedural and institutional aspects of governing UOG production matter, too, and can systematically exclude people from participating in making decisions about where, when, and how UOG production takes place [13–16]. Conversely, policies and inequitable processes also actively disempower members of the public or exclude them from decision-making, though private operators can exercise strong influence over policy processes [15]. These institutional barriers make UOG production a *chronic* stressor – which can be more insidious, negative, and, significantly, can generate longer-term mental health impacts such as self-reported depression [17]. Indeed, my data highlight two key institutional barriers driving negative mental health impacts for people living near UOG production – namely: 1) *uncertainty,* due to inaccessible, untransparent information about environmental and public health risks and 2) *powerlessness* to meaningfully impact regulatory or zoning processes.

The state's institutional context and (lack of) transparency here is key, given the US's federal regulatory vacuum. The Colorado Oil and Gas Conservation Commission (COGCC) is the main regulatory body in Colorado, overseeing *and* permitting UOG production in a state that considers itself a regulatory leader [5,18,19]. Historically, the COGCC has an intrinsic conflict of interest because its dual mission has required it to encourage oil and gas production, while also protecting Colorado residents and ecosystems from risks of UOG production [20]. The COGCC has been the target of persistent criticism for working with the oil and gas industry in Colorado and for giving preferential treatment to industry, which has led to compromised enforcement of UOG regulations and reliance on self-regulation [21].

Disallowing local control of UOG production has been controversial in Colorado, where many municipalities retain Home Rule – the ability for communities to zone and regulate other land uses and economic activities within city limits. However, the oil and gas industry remains one of the few industries exempted from Home Rule through state preemption [4,15,18]. Local communities have tried to place moratoria or bans on UOG production, but they have been sued by the Colorado Oil and Gas Association (COGA), a powerful pro-industry lobbying group in Colorado. In 2016, amid several local moratoria or bans and COGA's repeated lawsuits, the Colorado State Supreme Court ruled that local communities did not have the right to limit UOG production [22]. People responded vociferously, with a ballot measure to increase setback distances of wells from homes and sensitive areas. Though it did not pass, over 40% of Colorado voters supported it – a surprising outcome, given that UOG operators and industry lobbyists spent an estimated $30 million to counter the ballot measure, compared to proponents' budget of just $1 million [23]. And recent state senate legislation, though still being codified, now requires the COGCC to prioritize environmental and public health outcomes when permitting. Much like the federal Juliana V. US case on intergenerational climate justice, young adults waged similar legal battles in the Martinez v. COGCC case, with state courts ruling that the COGCC must consider public health and environmental well-being in their permitting decisions. However, the Colorado Supreme Court recently overturned that decision. Currently, then, only two options remain for communities or members of the public to challenge siting of UOG production, namely: finding alternative sites and placing wellpads near *other* neighborhoods (eliciting a Not in My Backyard (NIMBY), divide-and-conquer dynamic) or creating a memorandum of understanding with industry operators regarding how UOG production will be conducted or monitored (but with production still taking place) [15,18]. These battles continue, but so does production – creating an institutional context where uncertainty and powerlessness thrive, as I show below.

Linking my findings to work on neighborhood industrial activities and public and mental health [10], I show how it's not only the scale and density of UOG production that matter – but also procedural inequities encountered in this *institutional context* that make production a chronic environmental stressor [17,24,25]. Below, I illustrate how institutionalized procedural inequities create barriers to: a) accessing reliable, useful information and b) exercising participatory power – leading to adverse mental health outcomes.

2. A review: industrial environmental stressors, environmental public health, and UOG production

2.1. Industrial processes as environmental stressors

Stress experiences significantly affect people's physical and mental health throughout the 'stress process' [26]. Chronic stressors – or "relatively enduring problems, conflicts, and threats that many people face in their daily lives" [27] – can have longer-term, more significant, and more severe impacts on mental health than temporary life events [28,29], while also being inequitably and intersectionally distributed across populations [30,31]. Various stressors can be attenuated by positive experiences of high levels of mastery, self-esteem, or social support [32]. After all, "a sense of control…[or] a generalized belief that most circumstances in one's life are under one's personal control,… [and] social support refer[ring] to emotional, information, or practical assistance" powerfully counter stress [17].

Neighborhood industrial activities can generate significant sources of stress. Downey and Van Willigen [10] assert "local industrial activity should be considered a neighborhood-level chronic stressor that, like employment conditions and neighborhood poverty, negatively impacts mental health". Industrial noise can create stress and "may be perceived as a visible sign of social disorder that…increases psychological distress" [10]. Industrial activities can create visible neighborhood disorder or contamination [33] and can increase psychological distress as people perceive their local environment to be unhealthy [34,35].

Institutional contexts – under-studied in the UOG production context – and especially powerlessness and lack of information from institutions figure centrally in how we process chronic stress. Experiences of personal powerlessness have been established as important predictors of psychological distress [17,35]. Living near industrial activities can increase this feeling of powerlessness [10], especially when people have continued or long-term exposure to negative neighborhood conditions like industrialization or contamination [34,36]. Research shows that "it is reasonable to expect that many people find residential proximity to industrial activity to be *chronically* stressful and, therefore, psychologically distressing" [10]. Therefore, even in contexts where residents can negotiate memoranda of understanding (MOUs) with industry operators about the terms of UOG production, often production still occurs [15,37] – sometimes less than 1,000 feet from people's homes, when proximity matters [38] – and potentially generates stress. This should be rigorously examined, then, as neighborhood-level UOG production proliferates.

2.2. Neighborhood UOG production, public health risks, & stress

As UOG production continues to move into people's neighborhoods, researchers learn more about the potential environmental public health risks it generates. These include: largely undisclosed chemicals used in the process, which may be carcinogenic or cause endocrine disruption [39,40]; significant, potentially unsafe levels of air pollution [41,42]; elevated rates of childhood cancer [43] and birth defects [44]; industrial accidents [45]; under-reported spills and increased risk for surface water contamination [46]; and multiple other risks to

environmental public health [47,48]. Recent research has confirmed acute adverse environmental public health impacts for people living within 2000 feet of oil and gas wellpads, experiencing short-term effects such as dizziness, nausea, respiratory issues, and skin and eye irritations from temporary exposure to carcinogens such as benzene [2]. Uneven regulations across places and different behaviors by various operators have been shown to result in different outcomes for risky, polluting behaviors such as flaring natural gas, which can lead to variations in risks and exposures across different locations as well [49].

Social scientists have captured divergent public responses and outcomes [4,50], with varied perceptions of risk across and within study locations [51]. Researchers have found it difficult to generalize people's perceptions of UOG production across study locations, though, partly because research is done unevenly across geographic locations and partly because methods utilized in each study can vary so greatly and have different levels of rigor [52]. People living atop the Marcellus Shale play in the eastern U.S. report increased employment and tax bases but express concerns related to environmental degradation and increased noise and traffic [53,54]. Across other regions, perceptions of the industry's effects reflect people's ambivalence – from Texas and Ohio [55,56] to Louisiana [57] and Colorado [37]. This includes spaces where agricultural land, food production, and UOG production overlap, as farmers and ranchers navigate potential structural disadvantages [58] and other risks but also positive (if temporary) outcomes for their livelihoods [59]. Intersections of resource extraction, environmental shocks and stressors, and social disruption have been well-established across sociological research, including through the lenses of historical and current community natural resource dependence [60,61]. Further, variations in regulations across different places, and especially international contexts [62], can also result in drastic differences in how the industry is perceived, the pace at which UOG production is implemented, and even whether it is adopted at all in places like the European Union with more precautionary approaches [63]. While the shocks and stressors experienced amid UOG production are not surprising, they need to be more systematically analyzed for relationships to stress and mental health.

Researchers are beginning to find significant psychosocial and mental health outcomes related to UOG production, outcomes that are particularly deleterious for individuals living in a "fracking community" [64]. Micro-level impacts of UOG production may include: systemic loss of trust in leaders, industry operators, and neighbors; persistent feelings of concern about environmental degradation; concerns about pollutants and potential health risks; and general mental distress [65–67]. Meso-level manifestations of psychological stress and poor mental health outcomes related to UOG production include: 'collective trauma' and loss of community unity, lifeways, and social fabrics [55,68,69]; social disruption from boom and bust cycles [70]; gendered imbalances [71] and distressing and alienating working conditions [72], especially for male workers [64,73]; increased sex trafficking around oil and gas 'mancamps', which can particularly affect Indigenous women [74,75]; and various disparities in resource and information access between industry and people living amid drilling [76].

Researchers have begun to examine impacts to quality of life (QOL), relevant here because QOL relates to chronic stress [28] and because relationships between people's QOL, stress levels, and UOG production need to be more rigorously, holistically, and comparatively assessed [12]. Key to QOL is the freedom to develop one's capabilities and exercise them across all aspects of life, including: health, secure economic livelihoods, the ability to exercise agency, and the ability to exercise control or have genuine choice in life situations, which requires access to useful information [77]. Early findings indicate UOG production negatively affects these and other aspects of daily life. Studies have shown that work, social, and community aspects of QOL have been affected in North Dakota's Bakken oil field [78]. Stress has also emerged as a consistent and pronounced outcome of living near UOG production in other drilled regions across the U.S. [79–82]. In Australia, Lai et al. [83] found that rural populations living near coal seam gas development had mixed perceptions but were negatively affected overall due to resource and community losses, and people reported feeling more acute losses when sacred or valued landscapes were degraded [84].

These studies consistently show UOG production can create stress. But two voids remain: 1) examining how UOG production near people's homes becomes a *chronic* environmental stressor with longer-term impacts on mental health and 2) identifying and analyzing the institutional mechanisms or processes behind these outcomes. I address these voids by showing how two institutional drivers related to procedural inequities – uncertainty about and limitations of transparent information about risks and people's powerlessness to participate in decision-making – make UOG production a chronic environmental stressor with negative mental health impacts.

2.3. Procedural equity & public health amid UOG production

Access to useful, translated, and reliable information about environmental and public health risks from trusted institutions matters [37,85], particularly where neighborhood industrial activities meet institutional processes [86]. Further, the ability to use this information to then directly participate in related policy decisions [87] represent key procedural aspects of environmental justice – but are still underexamined in relation to mental health outcomes amid dense localized UOG production.

Procedural equity moves beyond distributive injustices (where environmental 'bads' and 'goods' are sited) to focus on institutional processes that *create* inequities [88–90]. Procedural equity includes: a) *recognition* of individual, community, and cultural differences and histories, especially for involved or affected peoples; b) opportunities for members of the public to *authentically participate* in making decisions about land and resource uses and to have *access to information that is useful and transparent* to aid in making these decisions; and c) safe spaces to facilitate the community's capacities for growth and empowerment [88].

Importantly, this means more than access to general online information [86] and relates to being able to access *scientific and peer-reviewed information* about localized environmental and public health risks for people who live less than 1,000 feet from wellpads and other infrastructure. Recall that this study began in 2014, when there was a shortage of this kind of information, especially from trusted scientific and peer-reviewed sources. Even though studies ramped up by 2017 and were being published, people did not have equitable access to this information, especially peer-reviewed articles stuck behind paywalls, which can cost around $40 apiece to access. People can lose control over decisions about UOG production near their homes [91] and on their farms [58] and less powerful, poorer neighborhoods become the preferred sites of expansive UOG production [92–94]. This can happen even when people have the power to sign leases but are constrained by industry *meta*-power [15] and do not own mineral rights [18]. For instance, landowners can experience procedural inequity if they do not own their minerals [18,95] – or have ownership but little control over lease processes [15,58] or limited opportunity to form coalitions [96]. While surveys and quantitative analyses are deeply important and have captured divisions in Colorado [13,38], ethnographic data about these institutional processes are vital, yet scarce. Internationally, we see procedural inequities emerge as well – in the context of Australian unconventional development of coal seam gas [97] and United Kingdom UOG production [16,98] – though, again, institutional analyses are lacking. Institutional dynamics are key, in no small part because industry operators have assets, resources, and information, such as investment capital, political lobbying power, satellite imaging and seismic testing, which dwarf anything members of the public can access [99].

Social scientists need to more systematically assess, then, how UOG production affects stress – and how institutional contexts and levels of

transparency may allow UOG production to negatively impact people's mental health. Procedural inequities figure centrally at the institutional level – particularly people's systematic exclusion from accessing transparent information about localized risks and from affecting institutional processes. To help assess these multiscalar processes, I ask:

1) What mechanisms drive chronic stress for people living amid industrial UOG production?
2) What do these outcomes mean for people's mental health?
3) How do these mechanisms link to broader institutional processes and procedural inequities?

3. Data & methods

The National Institutes of Environmental Health Sciences, part of the National Institutes of Health, funded this three-year study through the R-21 grant program. Data collection was multi-sited, mixed methods, community-based, and conducted between 2014 and 2017 by a team of social scientists (led by me), epidemiologists, and exposure scientists. This study meets the call for more rigorous, multi-sited, mixed methods, and interdisciplinary research in energy social science [100] and uses ethnography [101] to address issues of power and justice [102].

Three northern Colorado communities – Greeley, Windsor, and Fort Collins – were our study sites. The study included survey instruments distributed to randomly sampled households from the three communities; in-depth, semi-structured interviews; participant and ethnographic observation at people's homes, production sites, and public meetings; and biomarker assessments of stress from a sub-set of participants who gave blood, hair, and cheek swab samples. This project relied on the expertise and collaboration of several official study community partners. Here, I draw from 75 interviews conducted primarily in Greeley and Windsor, since Fort Collins acted as our 'control' community given its then-moratorium on UOG production (since overturned after COGA filed a lawsuit). In-depth interviews allow researchers to capture complex and sometimes traumatic outcomes related to environmental risks [103], and they also allow for critical reflections on policy-relevant topics like energy production [104], especially when combined with other ethnographic methods.

Windsor, Colorado, located southeast of Fort Collins along Colorado's northern Front Range, straddles Larimer and Weld County. The community of about 21,700 residents [105] has seen increasing UOG production, as hundreds of new wells create a dense horseshoe of industrial production around densely populated neighborhoods. New developments have been designed to accommodate and conceal wellpads and infrastructure among homes, pedestrian paths, golf courses, and parks.

Greeley, Colorado, has a long history of oil and gas production, and thus economic dependence and cultural openness to UOG production when compared to Windsor and Fort Collins. Greeley is the largest town and cultural center of Weld County, Colorado – which ranks eleventh in the nation for oil production, sixth for agricultural production, and has one of the highest well-to-people density ratios in the U.S. [106]. Weld County has over 21,000 active wells – the largest number of any county in the U.S. aside from Kern County, California – and over 12,000 are directionally drilled [107]. Greeley's economy is powered by UOG production, a mid-sized university, and industrialized agriculture and ranching. Oil and gas production occurs within the city limits, though about 99,000 people live in Greeley [108]. The map below shows the heavy drilling in this part of Colorado (see Fig. 1).

Over 75 in-depth interviews were conducted over three years, and I continue to conduct regular fieldwork and interviews. Sixty-six of the 75 interviews included in this dataset (or about 88%) were conducted with people from Greeley, Windsor, or elsewhere in Weld County, given their close proximity to industrial UOG production. The other 9 interviews (about 12%) were conducted with people who lived in Fort Collins but worked in Weld County near UOG production or who spent much of their daily lives near UOG production through their work with community organizations, as elected community officials, or with the industry. I identified a little under half (40%) of interview participants through random selection from sampled, surveyed households; when people returned surveys, they left their contact information if they wanted to participate in the interview and/or biomarker study components. I then randomly selected participants from that pool for interviews. The remaining participants (about 60%) were selected using network sampling from initial interviewees and from information given during interviews with community leaders, regulators, industry operators, and members of community partner organizations.

Of the interviewees in this dataset of 75, about 90% of interviewees overall reported experiencing increased, chronic stress, and about 75% overall self-reported longer-term depression due to UOG production – and particularly because of the uncertainty and powerlessness they felt. The 10% who did not report chronic stress were mostly Fort Collins participants living away from production and the 25% not self-reporting depression (which includes the 10% also not reporting chronic stress) were mostly community leaders and people who worked with the industry in some capacity. Importantly, some of the people reporting stress and/or depression had wellpads, pipelines, and other infrastructure on their land but were still experiencing stress. Further, nearly all study participants - about 95% - reported some degree of uncertainty about the environmental and public health impacts of UOG production.

The research team had community partner organizations that initially connected us with study communities and helped us notify members of the public about community meetings we hosted to deliver data and take questions during the study. Most of these organizations worked to achieve more local and community control over UOG production, but they were not necessarily against UOG production. Other than acting as initial conduits to the affected communities and helping us publicize public meetings, these organizations did not overtly influence the research process; instead they acted as important gatekeepers and as valuable sources of knowledge about community dynamics and histories related to UOG production. While I did interview some members of these organizations, I was careful to assure this was balanced with interviews from members of the public not affiliated with those groups, industry employees, community leaders (some of whom were pro-development), and people with wellpads and other infrastructure on their land. Further, public meetings were consistently held at neutral locations, such as local churches or public libraries.

Each Windsor or Greeley interviewee (about 88% of interviewees) lived in close proximity, or within about half-mile, of UOG production activities, especially wellpads; often, multiple wellpads were much closer than that. This close proximity was a requirement of the sampling frame used for the initial survey-based phase of research, so carried over to random selection of interviewees; but it was also due to prevalence of production in Weld County. About 65% of study interviewees were women, which reflects the stronger presence of women in environmental, and especially environmental justice, action [109,110] – including in other communities with UOG production [111]. Matching Colorado's Front Range demographics, about 80% of interviewees were white, working- or middle- to upper-middle-class, and ranged from college-aged to retired. However, the remaining 20% of interviews were conducted with Latinx populations. This number was less than the percentage of Latinx people in Greeley, but this was because many Latinx individuals living amid UOG production were undocumented or otherwise vulnerable populations and were quite hesitant to talk to university researchers. For instance, when possible I interviewed participants living near Bella Romero Academy (a Weld County middle school with 89% Latinx enrollment, compared to Greeley's 36% Latinx population, and 92% of students from low-income families [107]), which was selected to host over 20 wellpads just hundreds of feet from the school athletic fields and about 1300 feet

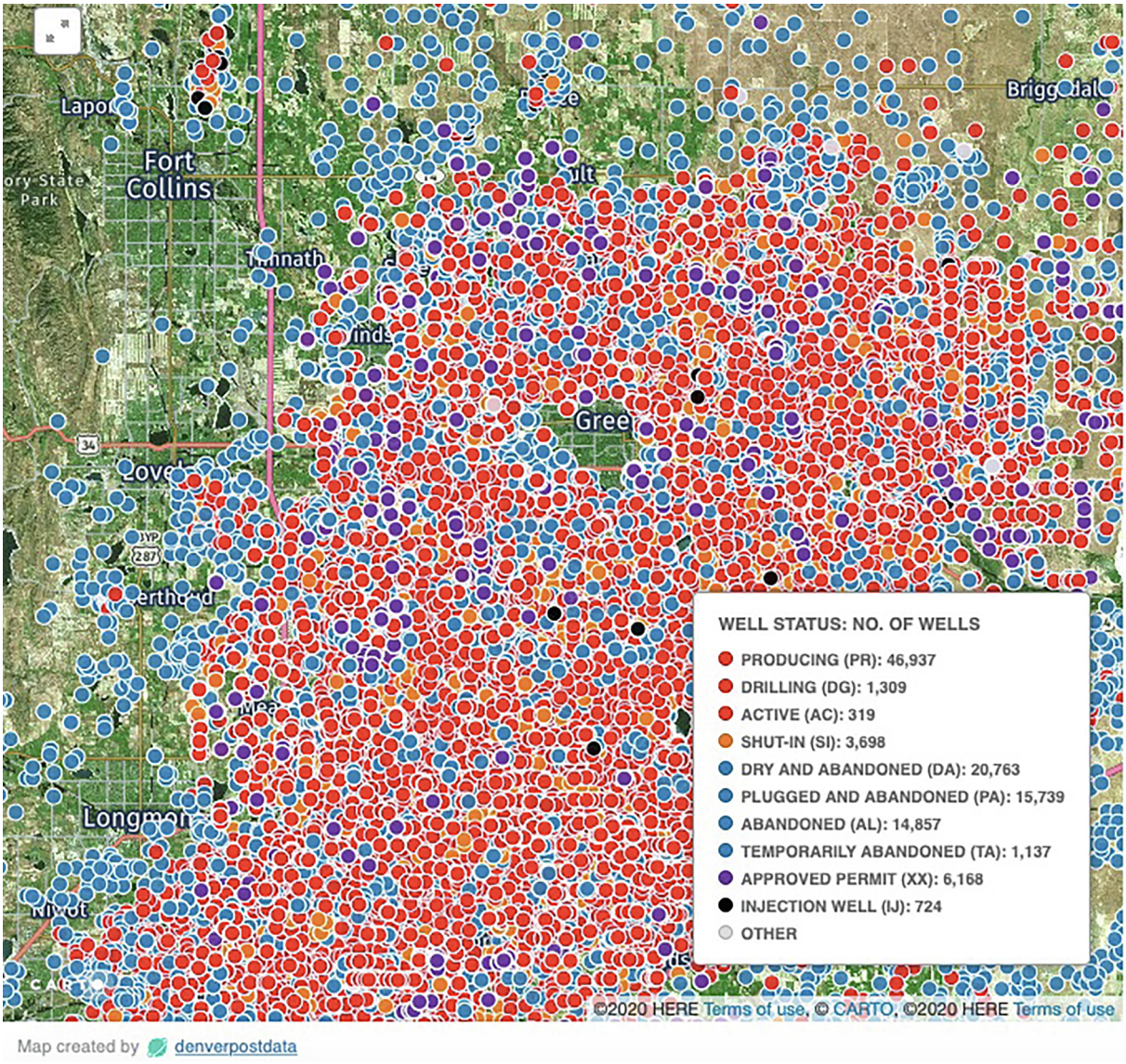

Fig. 1. Map: This map shows the number of wells along Colorado's Front Range in 2017. Greeley can be made out in the center of the map, and Windsor is located northwest of it. The number of operating wells has since increased to over 55,000 across Colorado.

from the school. But these interviews were difficult to secure and less frequent for the reasons given above.

The interview schedule included questions about people's daily lives and UOG's impacts on them, perceived benefits and risks of UOG production, and any related instances of increased or chronic stress or self-reported depression. Interviews lasted from 1 to 3 h and were conducted and recorded by the author in interviewees' homes or public locations. Each interview was transcribed verbatim, and fieldnotes were exhaustively recorded at the conclusion of each interview. Transcripts were divided equally among a three-person research team, led by me, which started with a list of likely codes from the literature and fieldnotes [112]. Team members coded interviews using this initial codebook, while also keeping notes of additional codes or sub-codes, which were discussed at subsequent meetings as we refined and further specified our codebook [113]. During meetings, we each brought and focused on 5 interviews from each group – for a total of 15 interviews that we rigorously discussed to create our master codebook. We continued to meet and also exchanged interviews between meetings, to assure that we had achieved inter-rater reliability across all interviews [114]. I then verified uniformity of coding across all interviews, to assure continued inter-rater reliability as we completed the coding process.

Participant observation consisted of hundreds of observations since 2014. As my social science team reviewed thematic findings from interview data and refined our codebook, participant observation data helped confirm or refine our findings [112,115]. I held interviews in people's homes, walked their fencelines, and saw 30-foot sound walls erected 15 feet from people's bedroom windows. I spent hours on gravel county roads, surrounded by truck traffic and industrial processes of UOG production amid people's homes and farms. Participant observation included attending meetings, from those held by community groups like Weld Air and Water and the League of Women Voters to various Colorado Oil and Gas Task Force, city council, county commission, and local planning commission meetings. The larger research team held public Community Q&A meetings throughout this three-year study period, where we delivered preliminary results and addressed people's questions. Similarly, I give many invited presentations to community, PTA, and church groups – allowing me to hear hundreds of informal reports about the public's experiences. Most recently, I co-hosted a community-led conference called the Medical Symposium on the Public Health Impacts of Oil and Gas Production.

4. Findings & analysis

My data show that the stresses of living near industrial UOG production can cause negative mental health outcomes for members of the public. Importantly, these mental health outcomes link in vital ways to institutional dynamics that helped generate *chronic* stress and led to lasting self-reported mental health impacts such as depression. Two particularly relevant institutional drivers of *chronic* stress emerged for people living amid UOG production, namely:

- *Uncertainty* about UOG production's localized environmental and public health risks because of barriers to accessing reliable, useful, transparent information and
- *Perceived powerlessness* to participate in decision-making about pace, scale, or outcomes of UOG production near their neighborhoods.

These multiple institutional barriers to procedural equity helped turn neighborhood UOG production into a *chronic* environmental stressor with negative mental health outcomes.

4.1. Inaccessible information, institutionalized uncertainty: UOG production's 'unknown' risks and mental health effects

Interviewees consistently observed that they were uncertain about nearly every long-term aspect of UOG production, and they were particularly uncertain about its public health risks and potential environmental hazards. *Barriers to accessing useful, transparent information* about UOG production's localized environmental public health risks and *a lack of public health information overall, especially when production initially boomed,* drove the uncertainty people consistently reported. Accessing useful, trusted, scientific, and peer-reviewed information proved elusive for most interviewees (about 90%), particularly those without access to academic journal subscriptions or academic partners. Importantly, such information was not forthcoming, or transparent, from public health or regulatory agencies like the COGCC. Instead, once information started emerging, it wasn't transparent; people had to invest significant time and money to access it, as there were conflicting media reports, biased government positions affected by industry presence, or because it was stuck behind journal paywalls. State institutional contexts that lacked transparency amplified people's uncertainty instead of counteracting it – thereby institutionalizing uncertainty.

People's uncertainty about UOG production's environmental health risks amplified their chronic stress. As one Greeley resident explained, "In 2013, we started getting lease things and it's like, 'I don't understand this.' There's no explanation. We tried looking if there was anything from the City or the county that would give you unbiased information. Just, you know, what are your rights, what are the benefits and the costs? It was just nothing." The sheer volume of unknowns about living close to industrial UOG production (often within 1,000 feet of wellpads), created chronic stress, according to interviewees. For instance, a Greeley woman who co-founded one of our study's community partner organizations observed how the lack of longitudinal data about UOG production's potential risks generated stress because policymakers and UOG operators rushed ahead with permitting production:

> What's stressful is the unknowns and how this industry is operating behind a curtain all the time…When you don't know the chemicals they're pumping down, you don't know where they're getting the water. You don't know how much these tanks are leaking. And there are all of these unknowns…I'll accept ugly. I'll accept inconveniences if it's providing jobs. What I won't accept is the chance that these are leaking toxins, and we're not being told. To me, that is stressful, the not knowing.

Additional representative quotations illustrate these patterns of uncertainty about risk and lack of institutional support and transparency. For example, a Windsor woman who moved to a densely drilled location to be closer to her son and grandchildren reported feeling unsafe and uncomfortable in her home. Constant uncertainty about UOG production's potential public health risks caused her to experience chronic stress. As she explained:

> I would say my stress levels have increased, just because you have the uncertainty of your health, and what the future is going to be like. Are they gonna be drilling under our neighborhood, and will I feel something then? Because they will be drilling under our neighborhood. Anadarko owns our mineral rights…I haven't finished putting up stuff, just got like pictures laying around, and it's like we haven't really moved in here. I just- I don't want to live here.

Another Greeley resident, with multiple wells visible from his deck, worried that the lack of useful information available to him or to policymakers exposed him to multiple unknown risks, even as production surrounded his home – creating chronic stress. He asserted:

> One of my concerns is that we don't know what the overall effects are…So how do you say [pauses] how do you tell people 'These are the parameters, if you're gonna drill.' If we don't have all the information to back it up, how can you [state agencies] regulate something? But in the meantime, how can you allow them [industry] to build close to somebody, you know? Or drill close when you don't know what the effects are?

For about 90% of participants, uncertainty about risks amid rapid expansion created chronic stress. Self-reported negative mental health impacts like depression emerged for 75% of interviewees as well, as production rapidly expanded in their neighborhoods – despite public health unknowns. As another Windsor interviewee explained:

> I think the case is out on fracking as a practice. The studies that have been done up in Wyoming clearly indicate that there may be some problems with fracking. There are a lot of other studies across the US that individuate similar outcomes, and I think the EPA has glossed over some of the problem areas that surfaced while those studies were being undertaken. And as a result, we don't really know, and it'll probably be 20 or 30 years before you really understand what the impact of fracking is…*Stress levels increased? Yeah, my blood pressure's way up right now, just talking about it* (emphasis added).

In another representative example, a retired woman who moved to Greeley to care for her grandchildren regrets her move because UOG production surrounds her home. She got involved in local resistance to drilling because of the lack of publicly available scientific information about UOG production's potential public health risks, even as the COGCC permitted wells around her home. But her activism created chronic stress and self-reported depression because of the perceived futility of her involvement in institutional processes. She observed:

> I think hydraulic fracturing is a bad practice. We're lab rats right now. They're learning about it as they're going…We don't know what the impacts are gonna be 20 years down the line…I retired and thought I was coming out here to spend my retirement age with my grandkids and my children and my neighbors. I bought my dream house and six months later, it just went to shit. And I hear this story over and over. People my age, who came out here to be with their kids and enjoy their grandkids. And what do I spend my time doing every day? [referring to her activism] *It's depressing*. It zaps your energy.

Another new Windsor resident said the unknowns of UOG production's public health risks were so stressful that she never would have moved to Colorado if she knew about the scale of industrial production near people's homes. The lack of useful, transparent information was especially stressful, given scant support from various institutions she thought would protect public health. As she explained:

> We bought this house and moved here. The first oil well was [right]

> down here [gestures out kitchen window],…and I was really shocked. I had no idea there was a well around here. And then we noticed in Weld Country, there were tons of oil wells going in. I wasn't very happy about it. And here I was, already bought this house. I think if I'd known all this was going on, I wouldn't have moved here…After we got here and found out…I'm shocked, absolutely shocked. I was under the impression that your cities and your government and everything is going to protect you from having an industrial site on top of your house.

These representative quotations illustrate a clear pattern across data: living amid the 20,000-plus wells facilitating industrial UOG production in Weld County created stress. The institutional context, especially inadequate access to and lacking information about potential public health risks, created *chronic* stress and self-reported negative mental health impacts.

Because people felt uncertain about public health risks, lacked affordable access to peer-reviewed scientific findings, and lacked transparent institutional support to access this information, many interviewees reported taking immense amounts of time (or money) to learn the science related to UOG production as it was published. As they observed, it was like they had acquired another full-time job. For instance, one Windsor woman who had led an effort in her neighborhood to move a set of 22 wellpads explained the significant amount of time she invested and stress she experienced in accessing information about public health risks and keeping state institutions transparent and accountable to the public. As she explained:

> Becoming involved with all this stuff has become like a job. To keep up with all the most recent information and the government laws and regulations that are coming out – it is a job to keep up with that. It really is…I guess that kind of bleeds into how I define my quality of life. I would really like to not to have to worry about something that I think is so basic - and that's air, water, and the soil I live on. But the neighborhood smells…I have called COGCC once, and they did come out. And [other interviewee] has called them multiple times. And…there'll be vents open and they'll go, 'Oh yeah, there were vents open. And they weren't supposed to be open, but we closed them'. Okay, so if [other interviewee] was not calling them, how long are they going to leave those open?".

The lack of access to transparent, useful information from the state created stress in her daily life. Given that the COGCC has around 23 regulators for over 55,000 wells operating in Colorado, residents living near UOG production sites felt that they often had to notify the COGCC when violations occurred. Even then, they were uncertain environmental public health risks were minimized – or even the nature of those risks more generally, given lacking information.

Clearly, uncertainty surrounding UOG production's potential environmental public health risks created significant stress. The lack of useful, transparent environmental public health information, barriers to accessing it, and a lack of institutional support and transparency in response to these concerns have made UOG production a *chronic* environmental stressor for people living near it, which, in turn, generated negative mental health outcomes, such as self-reported depression. These outcomes display important, institutionalized violations of procedural equity, specifically the inability to access vital information that can be used to protect public health and safety. Without institutional transparency, support, or access, people felt uncomfortable even at home, chronically stressed, and often depressed due to institutionalized procedural inequity.

4.2. Powerlessness & stress amid production: Unresponsive regulatory institutions and mental health outcomes

Across study data, powerlessness emerged as the second key driver of stress and negative mental health impacts of living amid drilling. People consistently expressed feeling excluded from decision-making processes related to UOG production and, consequently, powerless to affect the scale, location, or health outcomes of development. Powerlessness helped create chronic stress as affected people encountered significant institutional barriers to participation. Colorado's institutional context figured prominently here, as the main drivers behind feelings of powerlessness were identified as: a) institutional preference for rights of mineral owners and industry operators over communities and environmental public health and b) people's perceived lack of meaningful control over industrial production near their homes, including public health and regulatory policies – which had significant implications for procedural equity.

Many interviewees related their powerlessness to the way state institutions, including the Colorado Supreme Court and the COGCC, privileged rights of industry operators and mineral owners over communities and public health. I witnessed these dynamics in multiple public meetings I attended, and most of my interviewees focused on these inequitable meeting spaces and processes as well. In most public meetings, people were given little time to participate or ask questions, with most comment periods limited to 3 min per person – a key violation of procedural equity because it shrinks space for meaningful public participation. On the other hand, many interviewees observed that industry operators and representatives were given abundant time to present in other portions of the meetings and could even over-power smaller units of government. For instance, a Greeley woman observed how even local planning commissions were overridden by more powerful leaders in her community who had vested interests in UOG production's expansion. She explained how this led to the controversial siting of all those wellpads near Bella Romero Academy:

> This was a public hearing with Greeley's Planning Commission, and they turned it over to [oil company] to give their slideshow…They [oil company] proceeded to do about a two-hour presentation, so there was no time for public input. So 4 or 5 people out of a hundred people who wanted to protest got a chance to talk…Even on a local basis, it's very hard to be heard. And that's why people get very disheartened and disillusioned with the state regulations.

Across interviews, people linked their perceived powerlessness to important institutional gaps and procedural inequities. Said one Windsor woman: "I'm very concerned about the health risks, the pollution of the air, the water, the methane, the difficulty with people that have asthma in areas…I wish that we actually had a democracy that people were in power to say, 'No I don't want this in my community.' And we're not…I would rather be able to say, 'Not here'." Another Weld County woman observed these same patterns when she explained: "The problem is that this is coming in, and you feel helpless. You feel like you have no control over what's happening in your neighborhood, and I think control is a big issue. You should have some say over what is put within 1000 feet of your home." Yet another Greeley resident described institutional processes that actively excluded public participation: "We elect officials to hopefully run our local, state, and federal governments appropriately - to look out for our interests. And I know that you can't have something that satisfies everyone. But this is an example where it's running rough shod over a significant part of the population."

Even mobilized people felt unable to reduce production or affect COGCC permitting practices. For multiple marginalized neighborhoods, like those near Bella Romero, powerlessness is multiplicative and intersectional. This led many interviewees to feel hopeless, and many discussed having to fight feelings of exhaustion or burnout, especially for those that were the most dedicated to attending public meetings. One Greeley woman active in mobilizing one of our study's community partner organizations discussed her stressful lack of power in changing the location of multiple wells near Bella Romero Academy. She observed:

> I went up to the superintendent at the time, and I said 'I'm not okay

> with this'. And she was kind of cavalier, 'Well, the train's left the station, there's nothing we can do'. And I keep hearing this, 'There's nothing we can do.' And I'm thinking, 'Is this China?'. This is America! There is always something you can do. How can you hear Americans say, 'There's nothing we can do?'. What a crazy thing to say as an American in a democracy - 'There's nothing we can do'. There's this apathy that's really frightening.

As this illustrates, people felt powerless to change permitting decisions, particularly when institutional representatives discouraged them from participating and made them feel stuck in processes that excluded their voices and health concerns.

As another Greeley woman observed, directly citing her own chronic stress, "we don't live in an environment where government is supportive of our concerns or receptive to our concerns. And that adds to everyone's stress and that's not healthy for anybody in my book." Many interviewees, about 90%, expressed feeling similar chronic stress, given the way institutional processes like COGCC permitting practices enhanced the power of industry operators without creating comparable space for public participation in making decisions about industrial activities in neighborhoods. Rather than creating spaces for public participation and Home Rule, state regulators divided-and-conquered. Rather than listening to public concerns and scientific data to regulate UOG production and fulfill their mission to assure UOG production does not threaten public health and safety, they issued permits according to industry timelines.

These persistent institutional gaps helped create chronic stress and negative mental health outcomes because people felt colonized. The following interview excerpt eloquently illustrates this pattern that emerged across interview data:

> We have been colonized by the oil company. We are now their serfs…I'm still concerned about fumes even though they say they're catching it. Because my grandson was born a preemie, he was in the NICU fighting for his life and his breath. And now he's at school, and his favorite part of school is recess so he's going to be outside for all of this, causing problems. And the fact that they can put these things [wellpads] anywhere they want now and we have no say whatsoever, especially our stupid commissioners. They have decided that the property owners with the mineral rights have more rights than the surface owners. So people like us don't count.

Even if people own their land or some of their mineral rights, they cannot stop production in institutional contexts like this [15]. For instance, a Greeley resident shows how Colorado's state preemption created stress by disempowering even people who own their mineral rights, when he says:

> I mean, this is America, right? We own our land supposedly. Right? We get to make some decisions. And yet, just because they [industry operators] petition the commissioners to pool everybody, I can't say no. If one of my neighbors said yes, can't say no because then I'm depriving them. So that is stressful…to know that they were going ahead and do it [drill] anyway. That is stressful because I want to do the right thing. And how do you protest this? You can't even protest it…Yeah, we have no control. We have no control. And anytime you don't have control, you have a stress level. Mine's not as high as the lady who has the trucks going down her driveway. Can we chain ourselves to her driveway or something so they can't go down?

Even when community members brought hard-won information to decision-makers during public meetings, they report it was not meaningfully considered by policymakers. I confirmed this through my public meeting attendance, especially a series of meetings held by the Colorado Oil and Gas Task Force. People felt disregarded, which created stress, as one Windsor man illustrated when he observed "I've only been to a couple meetings, and it's so frustrating. You don't get questions answered, and you feel like you're being lied to. And I come home, and I can't sleep." Another representative interview excerpt from a member of a Greeley group fighting for local control over UOG production illustrated this stressful feeling of exclusion from participation in decision-making, even when the public brings peer-reviewed information about risks:

> One of the guys who's very involved…he does risk management assessment for businesses. He started evaluating some of this stuff going on with fracking…At one city council meeting, he presented several hundred pages full of peer-reviewed, documented evidence about the hazards involved, the health hazards for the communities. And the mayor literally took that pile of paper, set it to one side, and declared it as irrelevant…I've had a number of health issues I don't think would be quite as bad as they are if the industry didn't pump the things into the air and water that they do. But I have no way of proving that. The stress is not good.

The various forms of powerlessness analyzed above – combined with the lack of access to useful, transparent information – have significant effects on people's mental health because they exclude members of the public from understanding the risks they face and determining where UOG production takes place. As institutional processes, in turn, institutionalized people's powerlessness, these inequitable processes help generate chronic stress and negative mental health impacts, specifically as self-reported depression.

5. Discussion & conclusion

In this paper, I examine how UOG production acts as a chronic environmental stressor, negatively affecting the mental health of people living near the industrial activity. Specifically, people's experiences of *uncertainty and powerlessness*, particularly regarding exposure to potential environmental and public health risks, helped create chronic stress. Institutional contexts matter deeply. While UOG production near people's homes was stressful, *chronic* stress was generated by institutionalized procedural inequity, including: a) the public's inadequate access to useful, transparent information about UOG production's potential risks and b) limited power to meaningfully participate in decisions about how, when, and where production took place. This has vital implications for understanding how neighborhood industrial activities like UOG production can create chronic stress and negatively impact self-reported mental health [10].

My findings show that the institutional contexts in which Colorado UOG production are regulated and zoned are procedurally unjust and, thereby, nurture the *mechanisms* that can negatively impact the public's mental health. Institutional processes have not adequately addressed public health concerns – but have instead created patterned, systematized uncertainty and powerlessness. This institutional context, especially weak transparency and strong support for industry from the state (particularly the COGCC), drives procedural inequities by discouraging or excluding meaningful public participation. If people knew more about potential environmental public health risks – and had avenues to exercise decision-making power about development – members of the public might feel less chronic stress, even in the midst of production.

Other key lessons emerge. As longitudinal research is published, we continually learn more about UOG production's environmental public health risks [43]. But in Colorado's institutional context, as I have shown above, people feel hamstrung when trying to access or use scientific information to affect policy or production. The chronic stress of living near UOG production – while feeling ill-informed, excluded, and powerless – becomes so significant to public and mental health because *chronic* stressors have more lasting negative physical and mental health impacts [17]. *Institutional contexts are therefore key aspects of UOG production's long-term environmental public health and environmental injustice effects – while also creating negative mental health outcomes for people living near production.* These institutional contexts adjudicate people's access to information, how it is used, and how it may affect policy (or

not) – and the power people have to authentically participate in making those choices. Access to information and mastery or control over daily life, including neighborhood-level industrial production, are vital for quality of life [77] – particularly when your daily life is surrounded by wellpads. However, these aspects of the good life become casualties of living amid Colorado UOG production when state institutions fail to protect them.

By linking daily experiences of UOG production to institutional power dynamics that structure these inequities, we can see how powerlessness is deeply tied to untransparent and undemocratic institutional processes. As such, widespread, rapid implementation of UOG production in populated areas – without open access to public health information and participation in decision-making – amplifies environmental inequity and creates public health risks as production trumps procedural equity.

A few major lessons can be learned. My findings indicate that state policies and institutional practices that encourage secrecy, promote uncertainty, and shrink spaces for public participation create chronic stress and negatively impact mental health. People's daily lives become more stressful, less stable, and more alienating. At minimum, then, Colorado's main institution permitting and regulating UOG production, the COGCC, should provide more useful, transparent, and effective information and create more authentic opportunities for meaningful public participation in permitting and siting decisions, especially around residential areas. Other states could then follow suit. But it will take extensive work to build trust, given that the COGCC has not yet denied a drilling permit. Long-term trust-building like this would need to occur in spaces where people's concerns about environmental public health risks were discussed centrally rather than limited to 3-minute comment periods. It may, therefore, be most prudent for more trusted, third-party organizations to oversee this task, at least initially.

It remains unclear whether institutions will work to create space for procedural equity. Colorado's recent legislation (Senate Bill 181) offers some reason for optimism, but loopholes – and continuous permitting as rulemaking is delayed before and during COVID-19 – have generated public skepticism and concern that procedural inequity will once again empower industry to minimize public participation in writing rules meant to protect public health. Additionally, the legal context around UOG production remains fraught in Colorado. Adding to the Colorado Supreme Court's 2016 decision to deny local control for communities, the same court ruled against the Martinez decision – which would have required the COGCC to consider environmental and public health outcomes of UOG production when approving permits.

In these actions, we have nothing less than structural violence [116] – here, when one industry that potentially risks environmental public health is privileged by state institutions above the public. Violence is done to people's daily lives, their sense of safety and control, through procedural inequities that thrive within this institutional context. Stress permeates daily life – with little institutional support to counter that depressing powerlessness. If the public and UOG production are to coexist, these alienating and stressful dynamics will need to be addressed by evidence-based policies that also address UOG production's potential public health risks, including chronic stress and impacts to mental health.

Federal institutions should also take more comprehensive responsibility for regulating UOG production across the U.S. Because industry operators are exempted from key federal environmental regulations, such as the Safe Drinking Water Act and the Clean Water Act, states like Colorado scrambled to create their own regulatory approaches. Yet, these responses are often inadequate, as states lack the budgets, personnel, and UOG production-specific regulations to rigorously protect public health and safety [6,45]. The lack of federal guidance and the consequent regulatory checkerboard allow mechanisms of procedural equity – particularly uncertainty and powerlessness – to thrive within states.

The findings presented here could be strengthened and made more generalizable [52] by examining whether these outcomes occur across other states – given that we have early evidence they do [4,25,91]. It would also be interesting and useful to examine how these outcomes related to siting renewable and other energy productions systems – and perhaps to other instances where undemocratic processes negatively impact mental health.

Given the current federal regulatory environment and the staying power of policies like the 2005 Energy Policy Act, however, that remains unlikely. Local and state regulations must therefore begin treating UOG production as the chronic environmental stressor it is. Siting production near neighborhoods, schools, or hospitals can create chronic stress, as I've illustrated above. If living the 'good life' is a goal of a democratic society, the public needs more equitable paths to regulating industrial UOG production.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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